PCT/CH 2005/000064

REC'D 14 FEB 2005
WIPO PCT

PA 1268711

THE UNITED STATES OF AMERICA

TO ALL TO WHOM THESE PRESENTS SHALL COME:

UNITED STATES DEPARTMENT OF COMMERCE

United States Patent and Trademark Office

January 06, 2005

THIS IS TO CERTIFY THAT ANNEXED HERETO IS A TRUE COPY FROM THE RECORDS OF THE UNITED STATES PATENT AND TRADEMARK OFFICE OF THOSE PAPERS OF THE BELOW IDENTIFIED PATENT APPLICATION THAT MET THE REQUIREMENTS TO BE GRANTED A FILING DATE UNDER 35 USC 111.

APPLICATION NUMBER: *60/542,349*
FILING DATE: *February 06, 2004*

PRIORITY DOCUMENT
SUBMITTED OR TRANSMITTED IN COMPLIANCE WITH RULE 17.1(a) OR (b)

By Authority of the
COMMISSIONER OF PATENTS AND TRADEMARKS

N. WOODSON
Certifying Officer

17236 U.S.PTO
020604

22782 U.S. PTO
60/542349
020604

PTO/SB/16 (01-04)
Approved for use through 07/31/2006. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c).

Express Mail Label No. ER275611284US

INVENTOR(S)

Given Name (first and middle [if any])	Family Name or Surname	Residence (City and either State or Foreign Country)
Thierry	BIELER	Echichens, Switzerland
Laurent	CARDOLETTI	Rennaz, Switzerland

Additional inventors are being named on the 1 *separately numbered sheets attached hereto*

TITLE OF THE INVENTION (500 characters max)

Method And Device For Controlling A Synchronous Motor With Permanent Magnet From Zero Speed With Nominal Torque

Direct all correspondence to: **CORRESPONDENCE ADDRESS**

☐ Customer Number:

OR

☑ Firm or Individual Name	Deborah G. VandenHoff				
Address	Van Tassel & Associates				
Address	P.O. Box 2928				
City	Bellaire	State	TX	Zip	77401
Country	USA	Telephone	713-839-1749	Fax	713-839-1790

ENCLOSED APPLICATION PARTS *(check all that apply)*

☑ Specification *Number of Pages* 16

☑ Drawing(s) *Number of Sheets* 2

☐ Application Data Sheet. See 37 CFR 1.76

☐ CD(s), Number

☑ Other (specify) Additional Inventors

METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISIONAL APPLICATION FOR PATENT

☑ Applicant claims small entity status. See 37 CFR 1.27.

☐ A check or money order is enclosed to cover the filing fees.

☑ The Director is herby authorized to charge filing fees or credit any overpayment to Deposit Account Number: 11-0227

☐ Payment by credit card. Form PTO-2038 is attached.

FILING FEE Amount ($): $80.00

The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

☑ No.

☐ Yes, the name of the U.S. Government agency and the Government contract number are:

Respectfully submitted,

SIGNATURE [signature]

TYPED or PRINTED NAME Deborah G. VandenHoff

TELEPHONE 713-839-1749

Date February 6, 2004

REGISTRATION NO. 45,176
(if appropriate)
Docket Number: GLN-043US

USE ONLY FOR FILING A PROVISIONAL APPLICATION FOR PATENT

This collection of information is required by 37 CFR 1.51. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 8 hours to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: **Mail Stop Provisional Application, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

Copy provided by USPTO from the IFW Image Database on 01/04/2005

PROVISIONAL APPLICATION COVER SHEET
Additi nal Page

PTO/SB/16 (08-03)
Approved for use through 07/31/2006. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

Docket Number GLN-043US

INVENTOR(S)/APPLICANT(S)

Given Name (first and middle [if any])	Family or Surname	Residence (City and either State or Foreign Country)
Christian	FLEURY	Cotterd, Switzerland
Christian	KOECHLI	Neuchatel, Switzerland

[Page 2 of 2]

Number 2 of 2

WARNING: Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038.

Copy provided by USPTO from the IFW Image Database on 01/04/2005

Sensorless Low Speed

Low Speed invention

Confidential

Version 0.1

Copy provided by USPTO from the IFW Image Database on 01/04/2005

Document Control Sheet

Contents	Résumé des recherches sur l'extra low speed 60rpm
Author(s)	Thierry Bieler
Keywords	low speed sensorless brushless
Wordprocessor	WinWord 2002
Filename	Low speed-mod.doc
Status of document	In progress / in review / approved
Distribution	

Index

Copy provided by USPTO from the IFW Image Database on 01/04/2005

1 IMPROVEMENT COMPARE TO MICRO BEAM PATENT US 6,326,760

1.1 Improvement of the circuitry to measure the phase voltag

The method uses "momentary cut off of the powering of the motor phases" to measure substantially simultaneously each motor phase voltage (or at least 2 of them for 3 phase motor). When the motor is rotating really slowly, the measured phase voltage levels are really low: it is why their measurement on the complete voltage range would require a very high absolute accuracy. Using differential amplifiers with dividing bridge allows to measure mV in differential mode even these voltages are sometimes reaching voltage level equivalent to the level of the supplying DC voltage (by using for example the differential amplifier INA146 from Burr-Brown). This solution allows to measure the phase voltage without cutting off the powering of the motor phases, or with partially cutting off the powering. Using simple differential amplifier (with no input dividing bridge) is however sufficient when the powering of the motor is cut off before to measure.

The measurements directly differential between 2 phases allow to perform an arctangent function to obtain the position (from a 2 axis system). It can be noticed that the sign of the differential measurement allow to directly obtain the state of equivalent Hall effect sensors and to deduct the powering of the phases for a 120° commutation sequence (second solution with less resolution than the arctangent method).

The key part of this section for the invention is the fact that the circuitry used to measure the phase voltage has to be differential with a resolution good enough to be able to measure backEMF voltages introduced by vibrations of the motor at standstill when a pulsing torque is applied to the motor.

1.2 speed / torque controller

For very low speed, the motor can be stopped really quickly. Therefore it is very important for some applications that require a "difficult to stall electric drive", to implement a "quick to react" speed controller or torque speed characteristic controller. The square root of the sum of the back EMF voltage square results to a value proportional to the motor speed (here after measured motor speed). This represents instantaneous speed information that is obtained much faster than with other methods using for example the derivative of the position, or by calculating the variation of the position in function of the time. For one motor tested, the "momentary cut off of the powering of the motor phases" has been realized at a frequency of 2kHz and a PI speed controller has been implemented with coefficient designed to obtain the shorter reaction time without introducing instability.

The section is not fundamental for the invention, but it describes an advantage that can be obtained with the invention for some applications. More simple algorithm than "the square root of the sum of the measured phase voltage square" can give good results, like the sum of the absolute values of the measured phase voltages.

Copy provided by USPTO from the IFW Image Database on 01/04/2005

1.3 START up algorithm

Because the determination of the position based on the back EMF measured with a high resolution (hereafter the measured position), the measured position can be determined for a quite low speed level. A predefined commutation sequence (1 or 2 steps) to power the phases of the motor generates a motion of the rotor already sufficient to detect a back EMF and to determine the rotor speed (hereafter the measured speed). The system then continuously indirectly measure the position until a given predefined angle has been reached by the rotor (for example 10°).

The measured position calculated with the arctangent function with 2 arguments, will vary positively if the motor rotates in the direction defined as positive, negatively if the motor rotates in the direction defined as negative. This detail allows deducting the sense of rotation of the motor. If the sense of rotation corresponds to the one selected, the algorithm directly switches to a speed or a torque control algorithm, else a breaking current pulse if powered in the motor phases with a length and a duration big enough to reverse the motor speed and to perform again the algorithm described here above.

The start up algorithm described in this section is a possible application of the invention. Other way of implementing a start up algorithm using the same principle will be considered as equivalent. This start up algorithm can be improved by using the second key part of the invention described in section 2.1.

1.4 Oscillations

The methods described in section 1.3 have been used to generate an oscillating motion: as soon as the decreasing speed reaches a threshold level slow enough, a breaking current in open loop is generated to finish to stop the motor and to start the motor in the other direction with speed level low but already sufficient to detect the position and control the motor in close loop as describe in section 1.2 Of course the value of the inertia is important to design the length of the braking current pulse and its magnitude. The robustness of the system is increased because it is rapid to determine whether the start succeeded or not. In case the start fails, a new start algorithm is performed with no noticeable delay for the user.

The example described in this section is a possible application of the invention. Other way of implementing an oscillating algorithm using the same principle will be considered as equivalent. This algorithm can be improved by using the second key part of the invention described in section 2.1.

2 SATE FILTER LIKE KALMAN FILTER

2.1 Introduction

The methods described in section 1 are already giving good results but are sensible to noise for very low speed level down to the speed resolution of system: the motor may try to start several times before to succeed; in case of a big load peak, the motor may stop and lose its position and the system will need to perform the starting algorithm to get running again.

Copy provided by USPTO from the IFW Image Database on 01/04/2005

The drawbacks described here above have been suppressed and the quality of the control has been improved by taking into account the following physical reality: the motor position can not change quickly unless the speed reaches a non negligible speed level that will be within the system resolution. Therefore, if the speed is really low, it can be assumed that the position remains constant. This assumption will of course have a limit with the time, which may generate slow drift position for speed level below the system resolution. This last "position drift drawback" has been corrected naturally by the system because the measurement methods that "momentary cut off of the powering of the motor phases to measure substantially simultaneously motor phase voltages" is introducing torque variation generating position variation. With this position vibration the motor is reaching a speed level within the system resolution and accurate information about the position is again obtained. And as soon as the speed is negative, the measured position is shifted by about 180° compared to the preceding measured position: this allows deducting that the motor is rotating in reverse (because the method used to calculate the speed gives an absolute value of the speed).

Depending of the system inertia, the torque variation in a blocked motor state is sometimes not sufficient to reach a speed level within the system resolution. The torque variation is then artificially increased to reach a good speed level during the rotor oscillations (the load drived by the motor is blocked but the elasticity of the transmission allows the rotor to oscillate).

The key part of this section for the invention presented in the present document is the fact we take into account the following physical reality: the motor position can not change quickly unless the speed reaches a non negligible speed level that will be within the system resolution. The "method of generating rotor oscillations when the motor speed is below the system resolution" is a consequence and an advantage of the invention that can be used in certain application but that is not absolutely indispensable to implement the invention.

2.2 State filter

State filter or Kalman filter are especially suitable to take into account the physical reality used and described in section §2.1 (the motor position can not change quickly unless the speed reaches a non negligible speed level).

Such a filter as been implemented with the following algorithm:

$X = X_{-1} + (a*V * T + b*dP)/2$

X is the estimated position at the time t

X_{-1} is the estimated position at the time t_{-1}

X_m is the measured position using the back EMF at the time t

V is the measured speed using the back EMF at the time t

T is the time between the 2 consecutive measurements (t and t_{-1})

dP is the difference between X_m and X_{-1}, this difference being however limited to $\pm(c*VT+d)$

Copy provided by USPTO from the IFW Image Database on 01/04/2005

The parameters a, b, c and d are coefficients that are adapted to tune the algorithm in function of the system characteristics. For one of the examples tested, a = 1, b = 1, c = 2, d = 0. (With the condition (a+b)/2 = 1).

The algorithm presented here above has been limited to the equation absolutely necessary modelizing the variation of the position in function of the speed with a correction introduced with a feedback of the measured position. It is obvious that is not the unique solution to take into account the physical reality used and described in section §2.1. Adding complexity to the model by taking into account other parameters of the system like the inertia of the system will barely improve the performances and should be considered as equivalent if including a solution that can be considered equivalent to the one implemented here above.

2.3 Remarks

This section describes details of implementation that may improve the performances of the invention for some application but that are not indispensable to the invention.

In case the load of the motor is blocked while trying to rotates in the positive direction, negative speed is observed and the position is measured with a good quality: this is due to the elasticity of the transmission allowing a slight rotor motion back each time the powering of the motor phases is momentary cut off to measure quite simultaneously the motor phase voltages to determine the rotor speed and position. When the powering of the motor phase is turned on again, the rotor moves forward again. It is then possible to measure the rotor position even when the load is blocked. The term dP should then be able to compensate the term VT which is negative while the motor does not rotates.

A algorithm of confidence has been implemented with an integrator which increases by VT if the measured position is different than with more than 20° from estimated position. The integrator decreases by VT if the measured position is different than with less than 10° from estimated. As soon as the integrator becomes greater than 10000 (60°), the confidence algorithm concludes that the rotor may be blocked and the powering of its phases does not generates torque any more because the estimated position is no more right. The algorithm generates then additional torque variation to resynchronise the system on the right position.

2.4 Rotating motion versus linear motion

The invention has been described in this document for rotating motion using synchronous motor with permanent magnet, with at least 2 phases. But it should be generalized without limitation to linear motion, as the same principle are applicable to linear synchronous motors. The invention can also be applied to one phase motor with performances slightly decreased.

Copy provided by USPTO from the IFW Image Database on 01/04/2005

3 MEASUREMENTS

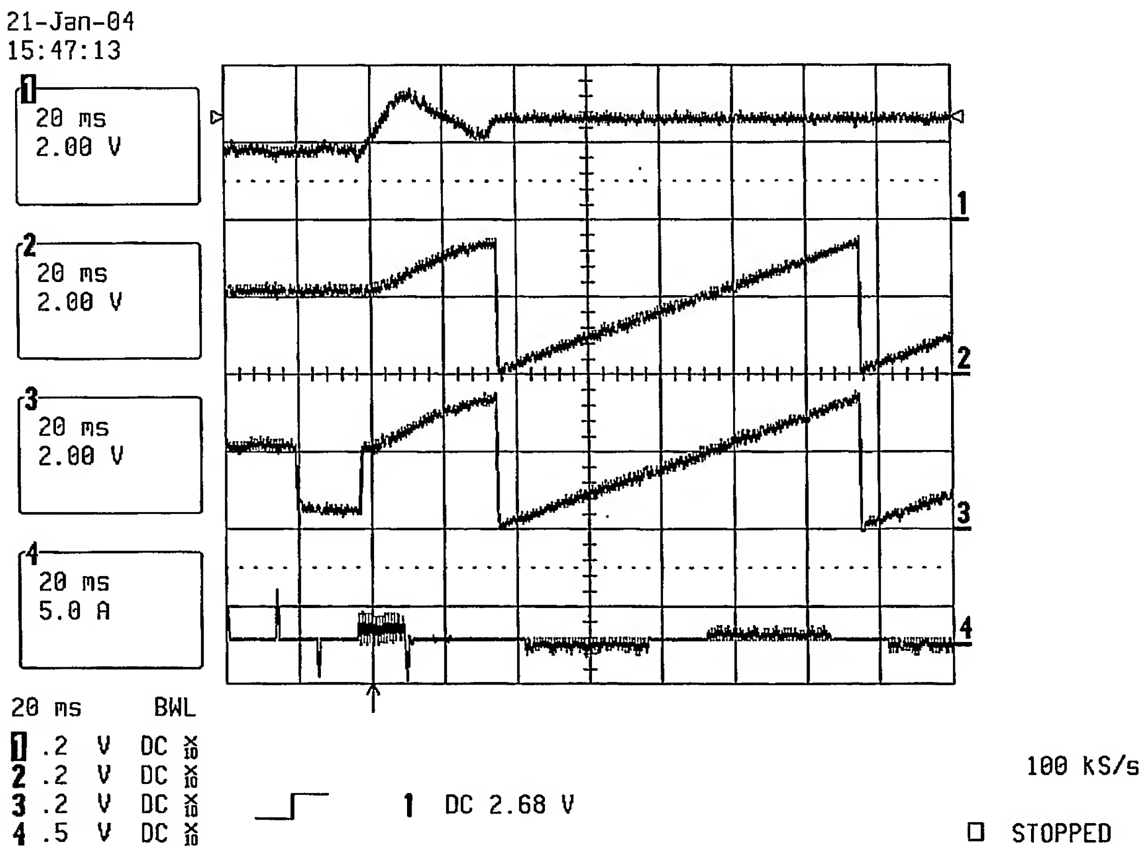
3.1 Introduction

The invention has been implemented and successfully tested for a 3 phase synchronous motor with permanent magnet, as well as for a 2 phase stepper motor with 200 steps per turn. This section presents measurements realized with the 3 phase synchronous motor with permanent magnet to illustrate the performances of the invention.

3.2 Start up using the low speed sensorless technology

Next figure presents a measurement of some key values during a start up of the motor with a load that is not blocked. The key values are:

CH1	measured speed (determined based on measured phase voltages)
CH2	estimated position (output of the state filter §2.2)
CH3	measured position (determined based on measured phase voltages)
CH4	measured phase current.



Copy provided by USPTO from the IFW Image Database on 01/04/2005

Comments:

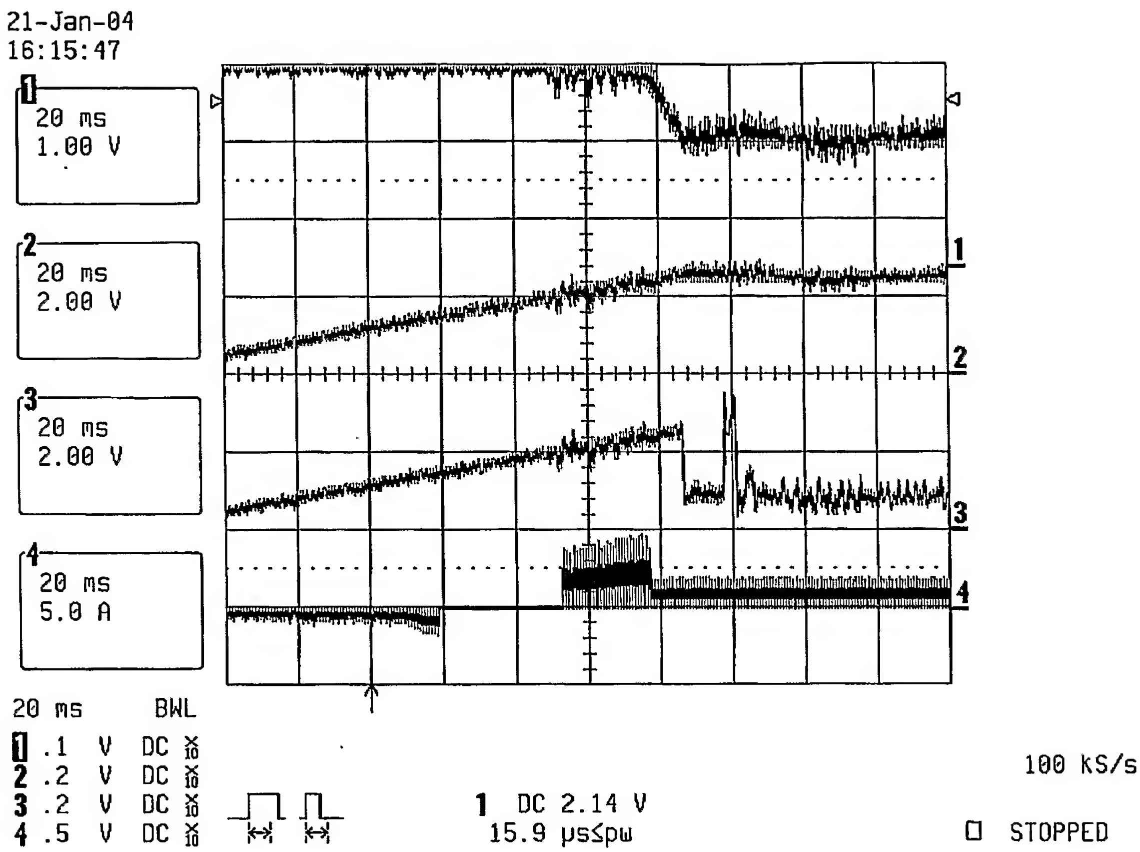
- Trace of CH4 shows the current during the start up algorithm. For this particular case, the rotor position is not known before to start the motor. It is why a first algorithm supplies the motor with current to generate torque during 1 ms in order to create a small rotor motion that will be non perceptible by the load but sufficient to measure phase voltage levels due to the back EMF within the system resolution. The measured speed and measured position can then be determined. Because a current supplied in 2 phases in series can generate a torque that can be positive, negative or even null in function of the rotor position, the supplied phase combination will be modified after each non successful try. Then as soon as the rotor position is known, the system can start the motor from zero speed with the nominal torque.
- Trace of CH2 shows the estimated position which is filtered compare to the measured position shown on CH3. The angular position is presented modulo 360°, the triangle shape corresponding to one revolution of the motor.
- Trace of CH1 shows the measured speed. This example illustrates the particular case of a speed control: the motor start with a speed overshoot before to be stabilized at the set speed.

3.3 Control of the torque in case of a blocked load using the low speed sensorless technology

Next figure presents a measurement of some key values during a stall of the motor resulting to a blocked load. The key values are:

CH1	measured speed (determined based on measured phase voltages)
CH2	estimated position (output of the state filter §2.2)
CH3	measured position (determined based on measured phase voltages)
CH4	measured phase current.

Copy provided by USPTO from the IFW Image Database on 01/04/2005



Comments:

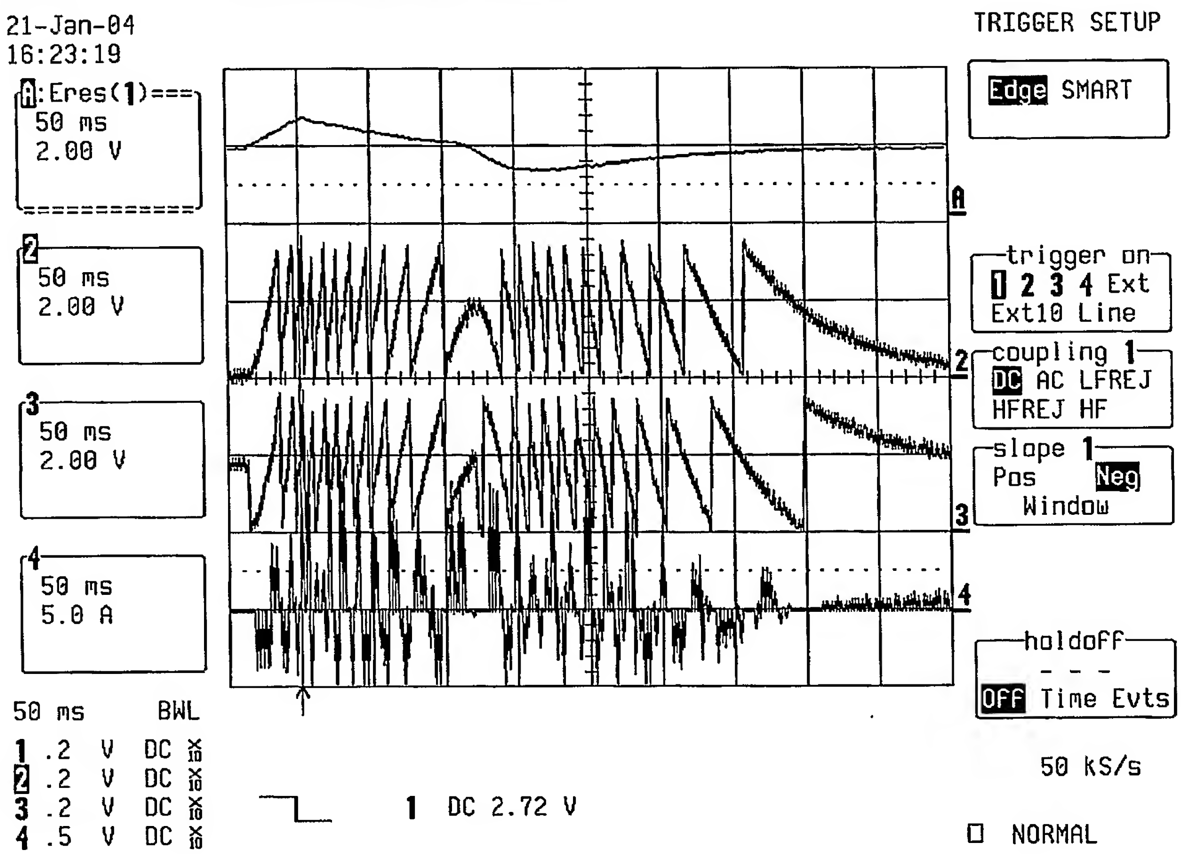
- Trace of CH2 shows the estimated position which is filtered compare to the measured position shown on CH3. The angular position is presented modulo 360°, the triangle shape corresponding to one revolution of the motor. Trace of CH1 shows the measured speed. This example illustrates the particular case of the motor rotating at a constant speed when a brutal increased of the load over the nominal torque of the motor will stall the motor. The speed decreases to zero when the motor stalls, the estimated rotor position of CH 2 remains then almost constant, with a small variation due to the fact that the controller applies the nominal torque to try to restart the motor (the system tested has been applied in a hand tool for which a constant load with no motion is difficult to apply on the cutting tool).
- The comparison of the estimated position of CH2 and the measured position of Ch3 illustrates the efficiency of the invention: the measured position varies quite a lot because it is determined from the measured phase voltages that are sometimes below the system resolution when the system is blocked. The measured position would not be really efficient to determine the powering of the motor phases, because any error in the position measurement will result for example to a torque in the reverse direction. Then using the estimated position really improves the quality of the control.

Copy provided by USPTO from the IFW Image Database on 01/04/2005

3.4 Oscillating motion with a control of the absolute position using the low speed sensorless technology

Next figure presents a measurement of some key values during a "round trip" motion of the load with a control of the absolute position. The key values are:

CH1	measured speed (determined based on measured phase voltages)
CH2	estimated position (output of the state filter §2.2)
CH3	measured position (determined based on measured phase voltages)
CH4	measured phase current.



Comments:

- Trace of CH2 shows the estimated position which is filtered compare to the measured position shown on CH3. The angular position is presented modulo 360°, the triangle shape corresponding to one revolution of the motor. Trace of CH1 shows the measured speed. This example illustrates a round trip motion of the load with a control of the absolute position. The motor start from one position and rotates eleven turns in one direction before to slow done to zero speed in the middle of the 12th revolution in order to rotates back 11 turns to the starting position. It can be noticed that the estimated position signal of CH2 stays nice and smooth when the

Copy provided by USPTO from the IFW Image Database on 01/04/2005

measured position signal of CH3 becomes wrong in the middle of the motion, just when the speed has to cross the zero level before the rotor rotates back.

- This test proves that the invention allows to implement a control of the absolute position of the motor and its load without a direct position/speed sensor, but only with a indirect position and speed sensor based on the analysis of the measured phase voltages measured in differential with a high resolution and an algorithm taking into account the physical principle of "a position not varying if the speed zero".

Copy provided by USPTO from the IFW Image Database on 01/04/2005

Method and device for controlling a synchronous motor with permanent magnet from zero speed with nominal torque

CONFIDENTIAL

Abstract

Method and device for controlling a synchronous permanent magnet motor from zero speed with nominal torque comprising the steps of:

- determining an optimized in function of the motor characteristics, said optimized frequency can be fixed or variable in function of the system status
- substantially simultaneously measuring the voltage of each motor phase or at least 2 motor phases (a phase voltage that can be measured phase to neutral and/or phase to phase and /or phase to an artificial neutral) with a high differential gain conditioning the measured signals to have a resolution of the sampled back EMF voltage corresponding to about 3 RPM,
- controlling the powering of each motor phase by momentarily cutting it off totally or partially at said optimized frequency,
- sampling at said optimized frequency the output signals from said measurement of each phase voltage before to turn on again the controlling of the powering of each motor phase,
- determining the rotor position and the rotor speed from the sampled signals,
- entering the determined rotor position and determined rotor speed in a state filter or said equivalent filter taking into account the physical reality of " the position not varying if the speed is zero", said state filter or equivalent filter calculating a filtered rotor position and a filtered rotor speed,
- controlling the powering of each motor phase as a function of the filtered rotor position and the filtered rotor speed,
- adapting if necessary said optimized frequency in function of the system status.

1

Copy provided by USPTO from the IFW Image Database on 01/04/2005

Inventors: **Thierry Bieler**, l'Oche l'Abbe 2, CH-1112 Echichens
Laurent Cardoletti, Chemin du Levant D, CH-1847 Rennaz
Christian Fleury, En Blanchet, CH-1585 Cotterd
Christian Koechli, Vy D'Etra 71, CH-2000 Neuchâtel
Assignee: **SA, Micro-Beam** (Neuchatel, CH)
Appl. No.:

Claims

What is supposed to be claimed at the moment:

1. A method for controlling a synchronous permanent magnet motor with at least one phase, a coil and a rotor, comprising the steps of:

determining an optimized frequency in function of the motor characteristics, said optimized frequency can be fixed or variable in function of the system status;

substantially simultaneously measuring the voltage of each motor phase or at least 2 motor phases (a phase voltage that can be measured phase to neutral and/or phase to phase and /or phase to an artificial neutral) with a high differential gain conditioning the measured signals to have a resolution of the back EMF voltage corresponding to about 3 RPM;

controlling the powering of each motor phase by momentarily cutting it off totally or partially at said optimized frequency;

sampling at said optimized frequency the output signals from said measurement of each phase voltage before to turn on again the controlling of the powering of each motor phase;

determining the rotor position and the rotor speed from the sampled signals;

entering the determined rotor position and determined rotor speed in a state filter or said equivalent filter taking into account the physical reality of " the position not varying if the speed is zero", said state filter or equivalent filter calculating a filtered rotor position and a filtered rotor speed;

controlling the powering of each motor phase as a function of the filtered rotor position and the filtered rotor speed;

adapting if necessary said optimized frequency in function of the motor characteristics in function of the motor speed and load.

2. Method according to claim 1, wherein said coil is powered in a unidirectional manner.

3. Method according to claim 1, wherein said coil is powered in a bi-directional manner.

4. Method according to claim 1, wherein the rotor rotational speed is determined by

2

Copy provided by USPTO from the IFW Image Database on 01/04/2005

calculating the sum of the squares of the voltages of each phase and by extracting the square root of this sum.

5. Method according to claim 1, wherein the rotor angular position is determined by first obtaining an equivalent 2 axis system with the measured back EMF voltages (for example using the 2 axis transformation if controlling a three phase synchronous motor, or in using the 2 measured phase voltages if controlling a 2 phase synchronous motor), extracting the angular position of the rotor using an Arctangent function.

6. Method according to claim 1, wherein the powering of the motor is switched as a function of the number of motor phases, the phase powering type, the motor type and the operating mode thereof.

7. Method according to claim 6, wherein as a function of the rotor position, only one type of switching is authorized.

Description

The present invention concerns a method for controlling a synchronous motor with a permanent magnet, without a direct sensor, including at least a phase, a coil and a rotor.

The invention also concerns a device for controlling a synchronous motor with a permanent magnet, without a direct sensor, including at least a phase, this device being powered by an electric power source.

Synchronous motors with permanent magnets, such as stepping motors, hybrid motors or direct current motors with no commutators, are currently well known and used to replace direct current motors with a commutator, the latter having a relatively short lifetime because of friction generated on the commutator by the carbon brushes.

In these motors with permanent magnets, an electronic phase switching circuit is necessary to replace the commutator function. Since this type of motor is synchronous, the rotor speed is the same as that of the rotating stator field. By removing the commutator and replacing it with an electronic circuit, the control logic has to know the position of the rotor to be able to perform the switching at the right time. This is usually achieved with Hall effect probes or an optical sensor called a direct sensor.

The presence of this type of sensor involves certain drawbacks. First of all, their cost has a non negligible effect on the cost of the motor. Moreover, the mounting thereof means that a certain volume has to be provided not just for the sensors themselves, but also for the electric connecting wires to pass. They therefore complicate assembly and increase the time thereof. Finally, the reliability of the system is thereby lessened.

Existing systems propose overcoming these drawbacks and providing a method and or a device for controlling a synchronous motor with a permanent magnet with no direct sensor (this feature was used in particular in the invention disclosed in the us patent published under

Copy provided by USPTO from the IFW Image Database on 01/04/2005

No. 6,326,760). Each motor having a monophase or polyphase winding around the stator creates an induced voltage due to the movement of the rotors magnet. The induced voltage of the non powered phases (measured by momentary cutting off their powering) allow the rotor position to be known and thus the motor to be speed and/or torque controlled.
The method described here above has a principal drawback: starting the motor "in close loop in function of the position" is not robust with variable loop, and this method request an open loop starting algorithm to reach a motor speed level high enough in order: 1.) the motion to have sufficient kinetic energies to prevent the motor to be stopped by the load between two sampling of the control algorithm 2.)the motor to induce voltages with a reasonable magnitude allowing the rotor position to be known and or and thus the motor to be speed and/or torque controlled.

The present invention proposes overcoming these drawbacks and providing a method and a device for controlling a synchronous motor with a permanent magnet used in motor or generator mode, this motor being able to be monophase, polyphase, unipolar or bipolar, and able to be controlled with or without pulse width modulation.

This object is achieved by a method as defined in the preamble and characterised in that it includes the steps of:

- determining an optimized frequency in function of the motor characteristics,
- said optimized frequency can be fixed or variable in function of the system status
- substantially simultaneously measuring the voltage of each motor phase or at least 2 motor phases (a phase voltage that can be measured phase to neutral and/or phase to phase and /or phase to an artificial neutral) with a high differential gain conditioning the measured signals to have a resolution of the back EMF voltage corresponding to about 3 RPM,
- controlling the powering of each motor phase by momentarily cutting it off totally or partially at said optimized frequency,
- sampling at said optimized frequency the output signals from said measurement of each phase voltage before to turn on again the controlling of the powering of each motor phase,
- determining the rotor position and the rotor speed from the sampled signals,
- entering the determined rotor position and determined rotor speed in a state filter or said equivalent filter taking into account the physical reality of " the position not varying if the speed is zero", said state filter or equivalent filter calculating a filtered rotor position and a filtered rotor speed,
- controlling the powering of each motor phase as a function of the filtered rotor position and the filtered rotor speed,
- adapting if necessary said optimized frequency in function of the motor characteristics in function of the motor speed and load.

Copy provided by USPTO from the IFW Image Database on 01/04/2005

The main difference between the present invention and the invention disclosed in the us patent published under No. 6,326,760 and incorporated by reference above can be resumed hereafter:

- the voltage of each motor phase or of at least 2 motor phases (a phase voltage that can be measured phase to neutral and/or phase to phase and /or phase to an artificial neutral) are now measured with a high differential gain conditioning the measured signals to have a resolution of the back EMF voltage corresponding to about 3 RPM.
- the rotor position is determined from the sampled back EMF signals by first obtaining an equivalent 2 axis system with the measured back EMF voltages (for example using the 2 axis transformation if controlling a three phase synchronous motor, or in using the 2 measured phase voltages if controlling a 2 phase synchronous motor), extracting the angular position of the rotor using an Arctangent function or an equivalent function taking into account non sinusoidal back EMF voltages..
- the determined rotor position and the determined speed are entered in a state filter or said equivalent filter taking into account the physical reality of " the position not varying if the speed is zero", said state filter or equivalent filter calculating a filtered rotor position, or a filtered rotor position and a filtered rotor speed,
- the filtered rotor position is used to control the powering of the motor phases.

The motor coil can be powered in a unidirectional or bidirectional manner.

According to one embodiment, the rotor rotational speed is determined by calculating the sum of the squares of the voltages of each phase and by extracting the square root of this sum.

In an advantageous manner, the rotor angular position is determined by first obtaining an equivalent 2 axis system with the measured back EMF voltages (for example using the 2 axis transformation if controlling a three phase synchronous motor, or in using the 2 measured phase voltages if controlling a 2 phase synchronous motor), extracting the angular position of the rotor using an Arctangent function or an equivalent function taking into account non sinusoidal back EMF voltages.

According to a preferred embodiment, as a function of the motor rotor position, a single switching type is authorised.

The object of the invention is also achieved by a device implementing the above method characterised in that it includes a power bridge powering the motor coil, a unit for controlling the powering of the coil, a circuit measuring the voltage of each motor phase and means for sampling, at an optimized frequency, the signals from the measuring circuit.

The device according to the invention advantageously includes a control unit arranged to control the switching of the powering of each of the motor phases, this control unit including at least one control programme depending on the motor type, the number of phases, the type of powering of the phases and the motor operating mode.

According to a preferred embodiment, the voltage of each phase is introduced into the control unit in the form of analogue signals obtained from differential amplifiers measured either phase to phase FIG. 1, and/or phase to neutral FIG. 2 and/or phase to an artificial neutral Fig.

Copy provided by USPTO from the IFW Image Database on 01/04/2005

3.

FIG.1 Phase-phase voltage differential amplification

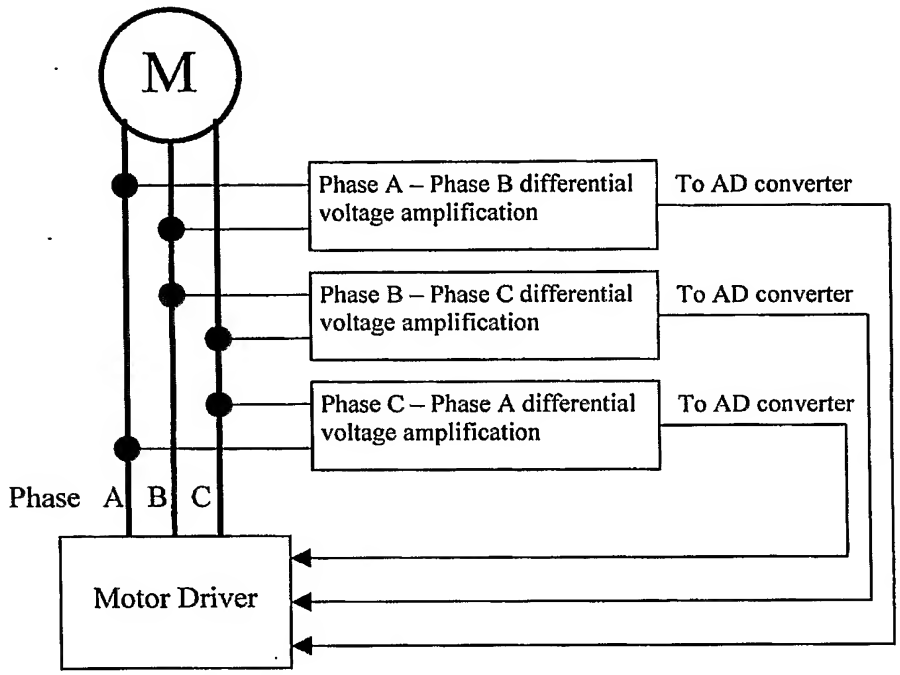
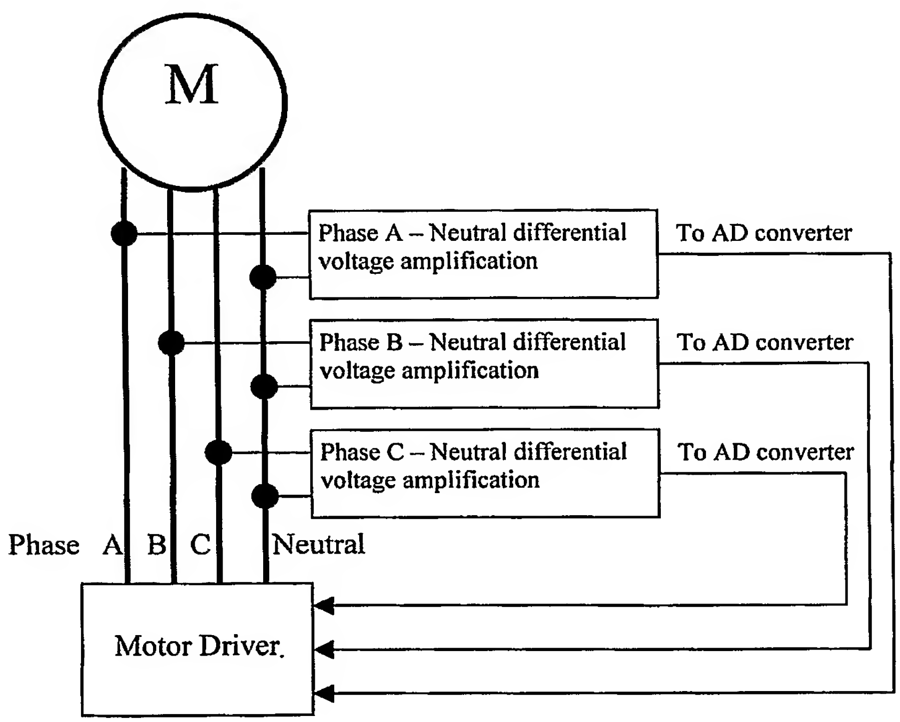
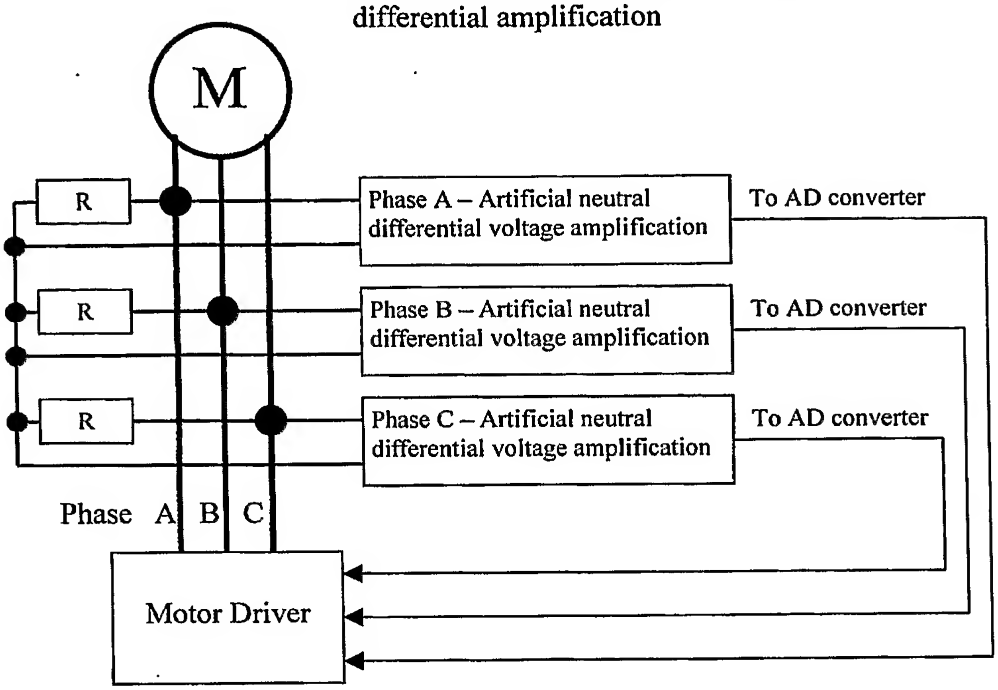


FIG. 2 Phase-neutral voltage differential amplification



Copy provided by USPTO from the IFW Image Database on 01/04/2005

FIG. 3 Phase-artificial neutral voltage differential amplification



The present invention is not limited to the embodiments described, but extends to any variants obvious to those skilled in the art. In particular, the type of motor which can be used is diverse.

Copy provided by USPTO from the IFW Image Database on 01/04/2005